Workshop Report:

Magnetic Nanostructures, Interfaces, and New Materials: Theory, Experiment, and Applications

Yves Idzerda (Montana State University)

To see what kind of impact that synchrotron research has had on addressing problems in material systems, all you needed to do was attend the two-day workshop from October 19-20 on Magnetic Nanostructures, Interfaces, and New Materials: Theory, Experiment, and Applications, organized by Elke Arenholz (the Advanced Light Source), Steve Kevan (Univ. of Oregon), and Yves Idzerda (Montana State University). This workshop with 20 talks from the international participants, brought together experts from different fields of magnetism research and synchrotron characterization, efforts often embodied within the same group, resulting in an exciting exchange of views and ideas. Although general in nature, the workshop did focus on the use of soft X-ray scattering (including resonant or anomalous scattering and magnetic scattering) as a unique tool for investigating many exciting materials.

The hope that synchrotron radiation could be used to obtain element-specific, site-specific, information with magnetic contrast of deeply buried magnetic systems has been realized at many facilities. The unique information obtained from polarized soft X-ray measurements is seen as an important contributor to the suite of experimental studies that have helped to define and understand outstanding problems in the field of magnetism and magnetic materials. An important example is the inclusion of high spatial resolution in techniques using polarized soft X-rays (magnetic microscopy). Workshop presenters Peter Fischer (LBNL) and others had stunning examples of transmission and electron yield magnetic microscopy. By imaging the magnetic domains of a ferromagnetic film, as measured by X-ray magnetic circular dichroism (XMCD) microscopy, and correlating that to the underlying domains of the anti-ferromagnet, as measured by X-ray magnetic linear dichroism (XMLD) microscopy, a number of groups may have delivered the definitive test in the elucidation of exchange bias phenomena, the asymmetric shifting of the magnetization hysteresis loop in one field direction.

The majority of the talks in this workshop focused on how the scattering of polarized X-rays could be used to study the new magnetic systems of recent importance. The first four presentations concerned data taken at four different synchrotrons. Sarnjeet Dhesi, now at the Diamond Light Source, showed how X-ray resonant magnetic scattering (XRMS) data taken at ESRF could be used to identify magnetic domain structures and even be used for observing orbital ordering in the manganites. Sujoy Roy (Univ. of California-San Diego) described how X-rays at ALS could be used to identify the mechanism of positive exchange bias in the Fe/FeF_2 multilayer system. For multi-component films, the interfaces can become quite complex as can the mechanisms for interface strain relief. Magnetic resonant scattering data taken at NSLS was used to quantify interface degradation one element at a time as shown by Yves Idzerda (Montana State Univ.). Jean-Marc Tonnerre (CNRS) presented X-ray magnetic scattering data acquired at the Swiss Light Source which shows excellent agreement between theory and experiment on interlayer coupling of Co/Cr/Gd multilayers. Later presentations included

work on tunnel barriers at the surface of layered manganites from the APS (John Freeland, APS), magneto-optics of lanthanides from BESSY (Kai Starke, Freie Universität Berlin), and magnetization dynamics at SSRL (Jo Stöhr, SSRL).

The middle third of the program was dedicated to the use of coherent radiation including coherent X-ray resonant magnetic scattering and magnetic speckle studies. Talks by Gerrit van der Laan (Darsbury Laboratory), Karina Chesnel (ALS), Larry Sorenson (Univ. of Washington), and Josh Deutsch (UC-Santa Cruz) showed that, although the phase reconstruction problem is still important in any speckle study, information is still obtainable in many important cases. Because of the successes of non-magnetic speckle, this remains an important technique to be further explored and refined.

Many of the talks showed how synchrotron radiation was revealing important information for manganites, lanthanides, spin ladders, and magnetic multilayers and nanostructures, but the final third of the program was full of promise as new classes of magnetic materials were discussed. R. Ramesh (UC-Berkeley), Kevin Edmonds (Univ. of Nottingham), Yuri Suzuki (UC-Berkeley), and Z.C. Qiu (UC-Berkeley) described new opportunities for multifunctional oxides, ferromagnetic semiconductors, orbital liquids, transition metal oxides, and coupled layers. Clearly synchrotron studies are making an impact in magnetic material development.

The workshop concluded with a visionary talk on magnetization dynamics and methods to probe the limits of magnetic systems by Jo Stöhr (SSRL). Although spatial resolution is making good progress, temporal studies in the femto-second range and below are lacking. He pointed out that currently magnetization dynamics are studied by pump-probe methods, where varying the time delay allows for the temporal mapping of fast dynamics in magnetic systems. Now pushing into the sub-picosecond regime for X-ray sources, this technique is appropriate for phenomena that are reproducible, but not appropriate for understanding the limits of a technology where the system may behave differently with each attempt. Studying and understanding the nature of the non-reproducibility is what will create avenues to overcome the current limits of technology. This can only be done in a single-shot measurement that will become commonplace with the next generation of light sources, the polarized FELs.